Fujitsu Semiconductor (Shanghai) Co., Ltd.
Application Note

MCU-AN-500080-E-10

F²MC-8FX FAMILY
8-BIT MICROCONTROLLER
MB95F430 SERIES

OPERATIONAL AMPLIFIER

APPLICATION NOTE

Revision History

Date	Author	Change of Records
2010-03-22	Folix	V1.0, First draft

This manual contains 18 pages.

CONTENTS

1 Introduction

In this document, we will introduce how to use the amplifier function on the MB95F430 series.

Chapter 2 gives an overview on operational amplifier.
Chapter 3 introduces the operations of operational amplifier.
Chapter 4 introduces Operational Amplifier setting procedure.
Chapter 5 introduces amplifier drivers.
Chapter 6 introduces amplifier application demo.

2 Amplifier Overview

The operational amplifier can be used to sense the ground current, and support front-end analog signal conditioning prior to A/D conversion. It can operate in either closed loop mode or standalone open loop mode.

■ Closed Loop Mode

The operational amplifier can be configured as a non-inverting closed loop operational amplifier.

It has six software-selectable closed loop gain options for ground current sensing according to different sense voltage values.

No.	Gain
1	10 V/V
2	20 V/V
3	30 V/V
4	40 V/V
5	50 V/V
6	60 V/V

■ Standalone Open Loop Mode

In this mode, the operational amplifier input pins are connected to external signals without any output feedback.

The standalone open loop mode is designed for users that can choose more flexible gain using external resistors.

2.1 Block Diagram of Operational Amplifier

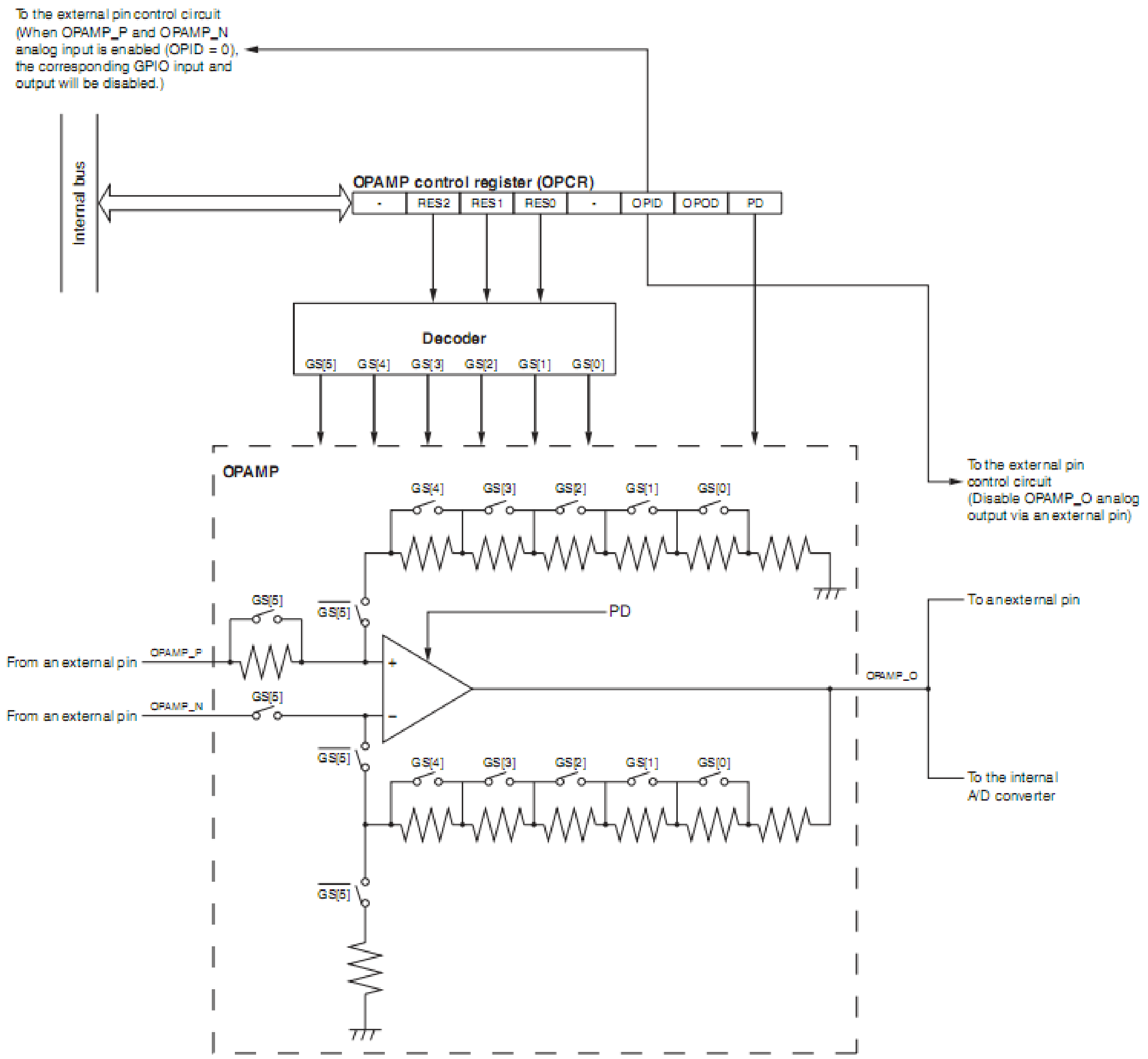

Figure 1 Block Diagram of Operational Amplifier

2.2 Pins of Operational Amplifier

The OPAMP uses the OPAMP_P pin and the OPAMP_N pin as the analog input pins of the operational amplifier, and uses the OPAMP_O pin as the analog output pin of the operational amplifier.
When GS [5] is set to "1B" and GS [4:0] is set to "00000B", the OPAMP will work as a standalone open loop operational amplifier.
When GS [5] is set to "0B", the OPAMP will work as a non-inverting closed loop operational amplifier. It provides six different closed loop gain settings through the software.

Pin Name	Pin Function	I/O Type	Pull-up Option	Standby Control	Settings Required for Using The Pin	Default Status
P60/OPAMP_P	GPIO/ OPAMP positive analog input	CMOS input/ CMOS output/ Analog input			OPCR:OPID = 0 (Enables analog input)	GPIO input disabled; GPIO output disabled; analog input enabled
P61/OPAMP_N	GPIO/ OPAMP negative analog input	CMOS input/ CMOS output/ Analog input	Unavailable	Available	OPCR:OPID = 0 (Enables analog input)	GPIO input disabled; GPIO output disabled; analog input enabled
P62/OPAMP_O	GPIO/ OPAMP analog output	CMOS input/ CMOS output/ Analog output			OPCR:OPOD = 0 (Enables analog output)	GPIO input enabled; GPIO output disabled; analog output disabled

2.3 OPAMP Control Register

The OPAMP control register (OPCR) is used to turn on and off the OPAMP, to enable and disable OPAMP analog output, and to enable and disable OPAMP analog input.
The register can also be used to set the OPAMP to operate as a standalone open loop operational amplifier, or a non-inverting closed loop operational amplifier with six different closed loop gain settings that can be selected by the software.

Address	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	Initial value
003EH	-	RES2	RES1	RES0	-	OPID	OPOD	PD	00000011B
	R0/WX	R/W	R/W	R/W	R0/WX	R/W	R/W	R/W	

PD	OPAMP power down control bit
0	Turns on the OPAMP.
1	Tunrs off the OPAMP.

OPOD	OPAMP analog output disable bit
0	Enables OPAMP analog output.
1	Disables OPAMP analog output.

OPID	OPAMP analog input disable bit
0	Enables OPAMP analog input.
1	Disables OPAMP analog input.

RES2	RES1	RES0	OPAMP loop gain setting bits
0	0	0	The OPAMP operates with a 60 V/V closed loop gain.
0	0	1	The OPAMP operates with a 50 V/V closed loop gain.
0	1	0	The OPAMP operates with a 40 V/V closed loop gain.
0	1	1	The OPAMP operates with a 30 V/V closed loop gain.
1	0	0	The OPAMP operates with a 20 V/V closed loop gain.
1	0	1	The OPAMP operates with a 10 V/V closed loop gain.
1	1	0	The OPAMP operates in open loop mode.
1	1	1	Setting prohibited

R/W : Readable/writable (The read value is the same as the write value.)
R0/WX : The read value is "0". Writing a value to it has no effect on operation.
- : Undefined bit
: Initial value

Figure 2 OPAMP Control Register

■ Functions of Bits in OPAMP Control Register (OPCR)

Bit name		Function
bit7	Undefined bit	The read value is always "0". Writing a value to it has no effect on operation.
bit6 to bit4	RES2, RES1, RES0: OPAMP loop gain setting bits	These bits select an OPAMP loop gain in closed loop mode from six options and can set the OPAMP to operate in open loop mode.
bit3	Undefined bit	The read value is always "0". Writing a value to it has no effect on operation.
bit2	OPID: OPAMP analog input disable bit	This bit enables and disables OPAMP analog input. **Writing "0":**enables OPAMP analog input. **Writing "1":**disables OPAMP analog input.
bit1	OPOD: OPAMP analog output disable bit	This bit enables and disables OPAMP analog output. **Writing "0":**enables OPAMP analog output. **Writing "1":**disables OPAMP analog output.
bit0	PD: OPAMP power down control bit	This bit turns on and off the OPAMP. **Writing "0":**turns on the OPAMP. **Writing "1":**turns off the OPAMP.

■ OPAMP Operating Mode Settings

RES2	RES1	RES0	OPAMP Loop Gain Settings
0	0	0	The OPAMP operates with a 60 V/V closed loop gain.
0	0	1	The OPAMP operates with a 50 V/V closed loop gain.
0	1	0	The OPAMP operates with a 40 V/V closed loop gain.
0	1	1	The OPAMP operates with a 30 V/V closed loop gain.
1	0	0	The OPAMP operates with a 20 V/V closed loop gain.
1	0	1	The OPAMP operates with a 10 V/V closed loop gain.
1	1	0	The OPAMP operates in open loop mode.
1	1	1	Setting prohibited

Notes:

•While the OPAMP is operating, modifying the settings of RES2, RES1 and RES0 is allowed, however, do not use the output signal of the OPAMP or execute A/D conversion until OPAMP output becomes stable.

•It is recommended to turn off the operational amplifier before modifying the settings of RES2, RES1 and RES0.

3 Operations of Operational Amplifier

The operational amplifier can be activated by setting the PD bit in the OPCR register using the software. It can operate in closed loop mode or open loop mode, depending on the settings of the RES2, RES1 and RES0 bits in the OPCR register.

■ Activating Operational Amplifier by Software

The settings shown in Figure 24.5-1 are required for activating the operational amplifier using the software.

	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
OPCR	-	RES2	RES1	RES0	-	OPID	OPOD	PD
	×	❍	❍	❍	×	0	0	0

❍ : Bit to be used

× : Unused bit

0 : Set to "0"

Figure 3 Settings for Activating Operational Amplifier

After the bits in the OPCR register are set as shown above, the operational amplifier will not start operating until it stabilizes.

■ Operations of OPAMP in Closed Loop Mode

Before being activated, the operational amplifier can be set to operate in closed loop mode in advance by setting RES[2:0] in the OPCR register to "000B", "001B", "010B", "011B", "100B" or "101B".

Six different closed loop gains are available to be used in closed loop mode. Select a desired closed loop gain by setting RES[2:0] in OPCR to the value corresponding to that gain.

Notes:

- In closed loop mode, connecting the P61/OPAMP_N pin to the ground is recommended.
- While the OPAMP is operating, modifying the settings of RES2, RES1 and RES0 is allowed, however, do not use the output signal of the OPAMP or execute A/D conversion until OPAMP output becomes stable.
- It is recommended to turn off the operational amplifier before modifying the settings of RES2, RES1 and RES0.

■ Operations of OPAMP in Open Loop Mode

Before being activated, the operational amplifier can be set to operate in open loop mode in advance by setting RES [2:0] in the OPCR register to "110B".

Note:

- While the OPAMP is operating, switching it from closed loop mode to open loop mode, and vice versa, is allowed, however, do not use the output signal of the OPAMP or execute A/D conversion until OPAMP output becomes stable.

4 Amplifier setting procedure

Below is an example of procedure for setting the operational amplifier.

● Initial settings

1) Set both OPCR: OPID and OPCR: OPOD to "0" to enable both OPAMP analog input and OPAMP analog output.
2) Set the feedback resistor and RES [2:0] in OPCR.
3) Set OPCR: PD to "0" to turn on the operational amplifier.
4) Wait until the operation amplifier stabilizes.
5) Start A/D conversion if necessary.

5 Amplifier Driver

This is OPAMP driver description.

5.1 Peripheral Usage

The MCU pins used as below:
OPAMP_N,used as amplifier negative input;
OPAMP_P,used as amplifier positive input;
OPAMP_O,used as amplifier output;

5.2 Driver Code

5.2.1 General Definition

```
typedef unsigned char   BOOLEAN;
typedef unsigned char   INT8U;          /* Unsigned  8 bit quantity */
typedef signed   char   INT8S;          /* Signed    8 bit quantity */
typedef unsigned int    INT16U;         /* Unsigned 16 bit quantity */
typedef signed   int    INT16S;         /* Signed   16 bit quantity */
typedef unsigned long   INT32U;         /* Unsigned 32 bit quantity */
typedef signed   long   INT32S;         /* Signed   32 bit quantity */

#define BOOL         BOOLEAN
#define BYTE         INT8U
#define UBYTE        INT8U
#define WORD         INT16U
#define UWORD        INT16U
#define LONG         INT32S
#define ULONG        INT32U
#define UCHAR        INT8U
#define UINT         INT16U
#define DWORD        INT32U

#define TRUE         1
#define FALSE        0

#define BYTE_LO(w)   ((UBYTE)(w))
#define BYTE_HI(w)   ((UBYTE)(((UWORD)(w)>>8)&0xFF))
```

5.2.2 Amplifier Routine

void AmpOpenLoop()

Return : none.
Parameters : none.
Description : open-loop setting.
Example : AmpOpenLoop();

```
void AmpOpenLoop()
{
   DDR6_P60=0;
   DDR6_P61=0;
   DDR6_P62=1;
   OPCR=0x60;//Amplifier gain is R3/R1
}
```

void AmpCloseLoop()

Return : none.
Parameters : none.
Description : close-loop setting.
Example : AmpCloseLoop();

```
void AmpCloseLoop()
{
   DDR6_P60=0;
   DDR6_P61=0;
   DDR6_P62=1;
   OPCR=0x40;//Amplifier gain is 20V/V
}
```

6 Typical Application

This is the typical application introduction.

6.1 HW Design

In this application, we will test the operational amplifier in the MB95F430K. The HW is designed as below. The R1, R2, R3 is used in open-loop amplifier.

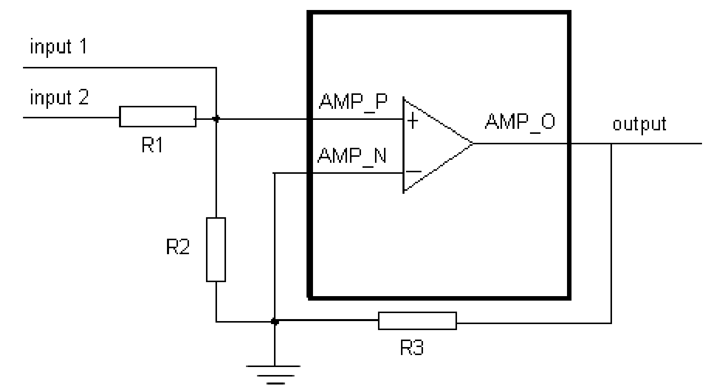

Figure 4 Hardware Design

6.2 Sample Code

void main(void)
Return : none.
Parameters : none;
Description : system main programm.
Example : main();

```
void main(void)
{
    __DI();
    __set_il(3);
    InitIrqLevels();

    WDTH =0xA5;//Disable WTG
    WDTL =0x96;

    WATR =0xEE;
    SYCC =0xF0;//Main Clock
    SYCC2=0xF4;//Main Clock
    SYSC  =0xBC;//BUZZ(P01)
    SYSC2 =0x02;//PPG(P73),Disable I2C
    while(!STBC_MRDY);
    __EI();

    AmpOpenLoop();
    AmpCloseLoop();
}
```

7 More Information

For more Information on FUJITSU Semiconductor products, visit the following websites:
English version:

http://www.fujitsu.com/cn/fsp/services/mcu/mb95/application_notes.html

Simplified Chinese Version:

http://www.fujitsu.com/cn/fss/services/mcu/mb95/application_notes.html

8 Appendix

9 Sample Code

main.c

```
#include "mb95430.h"
#include "TypeDef.h"

/*---------------------------------------------------------------------------*/
/* Amplifier Setting
/*---------------------------------------------------------------------------*/
void AmpOpenLoop()
{
    DDR6_P60=0;
    DDR6_P61=0;
    DDR6_P62=1;
    OPCR=0x60;//Amplifier gain is R3/R1
}

void AmpCloseLoop()
{
    DDR6_P60=0;
    DDR6_P61=0;
    DDR6_P62=1;
    OPCR=0x40;//Amplifier gain is 20V/V
}

void main(void)
{
    __DI();
    __set_il(3);
    InitIrqLevels();

    WDTH =0xA5;
    WDTL =0x96;

    WATR =0xEE;
    SYCC =0xF0;//Main Clock
    SYCC2=0xF4;//Main Clock
    SYSC   =0xBC;//BUZZ(P01)
    SYSC2 =0x02;//PPG(P73),Disable I2C
    while(!STBC_MRDY);

    __EI();

    AmpOpenLoop();
    AmpCloseLoop();
}
```

VECTORS.C

```
 #include "mb95430.h"

void InitIrqLevels(void)
{
```

```
/*  ILRx                    IRQs defined by ILRx */

    ILR0 = 0xFF;        //  IRQ0:  external interrupt ch0 | ch4
                        //  IRQ1:  external interrupt ch1 | ch5
                        //  IRQ2:  external interrupt ch2 | ch6
                        //  IRQ3:  external interrupt ch3 | ch7

    ILR1 = 0xFF;        //  IRQ4:  UART/SIO ch0
                        //  IRQ5:  8/16-bit timer ch0 (lower)
                        //  IRQ6:  8/16-bit timer ch0 (upper)
                        //  IRQ7:  Output Compare ch0

    ILR2 = 0xFF;        //  IRQ8:  Output Compare ch1
                        //  IRQ9:  none
                        //  IRQ10: Voltage Compare ch0
                        //  IRQ11: Voltage Compare ch1

    ILR3 = 0xFF;        //  IRQ12: Voltage Compare ch2
                        //  IRQ13: Voltage Compare ch3
                        //  IRQ14: 16-bit free run timer
                        //  IRQ15: 16-bit PPG0

    ILR4 = 0xFF;        //  IRQ16: I2C ch0
                        //  IRQ17: none
                        //  IRQ18: 10-bit A/D-converter
                        //  IRQ19: Timebase timer

    ILR5 = 0xFF;        //  IRQ20: Watch timer
                        //  IRQ21: none
                        //  IRQ22: none
                        //  IRQ23: Flash Memory
}

/*-------------------------------------------------------------------------
    Prototypes

    Add your own prototypes here. Each vector definition needs is proto-
    type. Either do it here or include a header file containing them.
-------------------------------------------------------------------------*/
__interrupt void DefaultIRQHandler(void);

/*-------------------------------------------------------------------------
    Vector definiton

    Use following statements to define vectors.
    All resource related vectors are predefined.
    Remaining software interrupts can be added hereas well.
-------------------------------------------------------------------------*/
#pragma intvect DefaultIRQHandler 0    //  IRQ0:  external interrupt ch0 | ch4
#pragma intvect DefaultIRQHandler 1    //  IRQ1:  external interrupt ch1 | ch5
#pragma intvect DefaultIRQHandler 2    //  IRQ2:  external interrupt ch2 | ch6
#pragma intvect DefaultIRQHandler 3    //  IRQ3:  external interrupt ch3 | ch7

#pragma intvect DefaultIRQHandler 4    //  IRQ4:  UART/SIO ch0
#pragma intvect DefaultIRQHandler 5    //  IRQ5:  8/16-bit timer ch0 (lower)
```

```
#pragma intvect DefaultIRQHandler 6    //   IRQ6:   8/16-bit timer ch0 (upper)
#pragma intvect DefaultIRQHandler 7    //   IRQ7:   Output Compare ch0

#pragma intvect DefaultIRQHandler 8    //   IRQ8:   Output Compare ch1
#pragma intvect DefaultIRQHandler 9    //   IRQ9:   none
#pragma intvect DefaultIRQHandler 10   //   IRQ10: Voltage Compare ch0
#pragma intvect DefaultIRQHandler 11   //   IRQ11: Voltage Compare ch1

#pragma intvect DefaultIRQHandler 12   //   IRQ12: Voltage Compare ch2
#pragma intvect DefaultIRQHandler 13   //   IRQ13: Voltage Compare ch3
#pragma intvect DefaultIRQHandler 14   //   IRQ14: 16-bit free run timer
#pragma intvect DefaultIRQHandler 15   //   IRQ15: 16-bit PPG0

#pragma intvect DefaultIRQHandler 16   //   IRQ16: I2C ch0
#pragma intvect DefaultIRQHandler 17   //   IRQ17: none
#pragma intvect DefaultIRQHandler 18   //   IRQ18: 10-bit A/D-converter
#pragma intvect DefaultIRQHandler 19   //   IRQ19: Timebase timer

#pragma intvect DefaultIRQHandler 20   //   IRQ20: Watch timer
#pragma intvect DefaultIRQHandler 21   //   IRQ21: none
#pragma intvect DefaultIRQHandler 22   //   IRQ22: none
#pragma intvect DefaultIRQHandler 23   //   IRQ23: Flash Memory

/*---------------------------------------------------------------------------
    DefaultIRQHandler()

    This function is a placeholder for all vector definitions.
    Either use your own placeholder or add necessary code here
    (the real used resource interrupt handlers should be defined in the main.c).
---------------------------------------------------------------------------*/
__interrupt void DefaultIRQHandler(void)
{
    __DI();                     // disable interrupts
    while(1)
        __wait_nop();           // halt system
}
```